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ABSTRACT

The focus of the study reported here was to investigate people's comprehension ability as a function of the number and type of negations embedded within sentences similar to those which might appear as premises in syllogisms. The subjects were one group of 11 Hispanic and four groups of Anglo students, with 15 in each Anglo group. Thirty-two logically complex sentences containing one, two, or three negations each and certain consistent elements (quantifiers, groups of similar objects, verb, etc.) were constructed, with four or five possible answer sentences corresponding to each sentence. Four sets of sentences were constructed, each containing the 32 basic sentences with portions of the sentences in different positions. One set was administered to the Hispanic group and to one of the Anglo groups; the other three sentence sets were administered to the other three Anglo groups. The subjects were to read the complex sentences and choose a less complex sentence that most closely corresponded to the meaning in the complex sentence. The results indicated that the subjects comprehended best the sentences with discrete rather than continuous descriptive information, and that sentences containing three negations were not well understood. The only difference between the Anglo and Hispanic groups was in the latency of response, a fact possibly explained by their acquisition of English as a first or second language. Possible explanations for the overall and specific findings are examined. (MSE)

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On the Relationship Between the Language of Natural Discourse and the Language of Logic: The Interpretation of Semantically Complex Sentences

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There is substantial body of research focusing on the effect that negations have on comprehension. Much of this research has resulted in some rather interesting findings. For example, one finding that has consistently emerged in numerous studies is that sentences containing negations take longer to verify than affirmative sentences (Just & Carpenter, 1971; Trabasso, Rollins & Shaughnessy, 1971; Wason, 1959, 1961; Slobin, 1965; Sherman, 1973, 1976). The only exception to this result surfaces in very context-specific instances called "plausible denials" (Wason, 1965; Arroyo, 1982), in which affirmative sentences take longer to verify than singly-negated sentences.

Early explanations of the increased latency in processing negations asserted that the additional transformations necessary to process negations take longer than the processing of affirmatives (Miller, 1962; Miller & McKean, 1964; Gough, 1965). More recently, linguistic and psychological factors have been used to construct information processing models which attempt to explain the mental processes employed when subjects process negations (Anderson & Reder, 1974). Some models, such as Carpenter and Just's Constituent Comparison Model (1975) are extremely accurate at predicting latency times as a function of the number of negations and the truth value of the statement.

In addition to the latency differences between affirmative and negative sentences, researchers have also found that subjects have more difficulties remembering negations. Mehler (1963) showed that sentences containing negations were harder for subjects to recall, while Clark and Card (1969) reported that subjects found sentences easier to remember if they transformed negations into affirmations. Other researchers have also found that subjects often combine two negations into an affirmative. In studies with negative prefixes such as in- and un-, Sherman (1973, 1976) found that subjects processed negations as they went along, for example, converting "not unprepared" to "prepared". Vazquez (1981) reported similar strategies whereby subjects cancelled the two negations in a statement such as "it isn't true that the dots aren't red"; however, a most interesting finding uncovered by Vazquez was that subjects were not predisposed to cancel the two negatives in the statement "it's false that the dots aren't red".

Research studies investigating subjects' ability to comprehend sentences

in which the number and type of negations were manipulated have consistently found that increasing the number of negations results in successive decrements in comprehension (Johnson-Laird, 1970; Legrenzi, 1970). Further, sentences where the number of negations reached three or higher were beyond the normal comprehension ability of subjects. This inability to comprehend more than two negations has been described by Sherman (1976) and others as "cognitive overload". Sherman claims that combining two negatives to form an affirmative is a cognitive construct which takes effort and space in the mental sentence processor; when a third negative is encountered, a system overload results and the "two-negative=affirmative" coding cannot be maintained.

A similarly rich body of research exists on syllogistic reasoning. Much of this research has focused on constructing models to predict subjects' invalid reasoning. For example, almost fifty years ago, Woodworth and Sells (1935) proposed the "atmosphere hypothesis" which claims that subjects like to choose conclusions whose quantifier (e.g. all, some, not) matches the quantifier in the premises. Johnson-Laird and Steedman (1978) attempted to explain subjects' predilection of certain valid conclusions over others. Using the context-free, quantifier-mixed premises,

Some As are Bs
All Bs are Cs

and asking subjects to state a valid conclusion which could be drawn from these premises, Johnson-Laird and Steedman found that the conclusion "some As are Cs" was a much more popular selection than the equally valid conclusion "some Cs are As." They claim that this is due to a "figural effect" where subjects are more likely to pick a conclusion linking A to C if they can form a continuous link from A to B to C. Recently, the "conversion model" has been popular (Revlin, Leirer, Yopp & Yopp, 1980). According to this model, subjects take a statement like "all Russians are Bolsheviks" and convert it in the process of comprehension to mean that not only all Russians are Bolsheviks, but also that all Bolsheviks are Russian.

A group of researchers are of the opinion that many errors in logical reasoning are due to the fact that the "rules" used in comprehending natural discourse are different from the rules governing logical reasoning. For

example, Henle (1962) observed that subjects tend to prefer "empirically reasonable propositions" to logical ones. She claimed that errors in deductive reasoning do not necessarily demonstrate subjects' inability to reason, but rather their tendency to disregard premises, or to interpret premises in an unintended way, or to disregard the logical task, or to introduce outside knowledge as an additional premise. Braine (1978) points out that common fallacies in syllogistic reasoning are due to introducing habits characteristic of practical reasoning and natural discourse comprehension into formal reasoning. Begg and Harris (1982) argue that people interpret logical statements according to well-understood but pragmatic principles of natural discourse. They claim that people do not play the logic game, but play a language game instead whereby people assume that the sender encoded the message sensibly and with some sensitivity to their needs as decoders; accordingly, an assumption is made that the message contains all of the useful information which the sender had at his/her disposal. Chapman and Chapman (1959) observed that conclusions chosen by subjects in syllogistic reasoning are based on behavior which often leads to correct solutions in everyday problem-solving situations, but which are disallowed in the traditional rules of syllogistic reasoning. The Chapmans claim that subjects use "probabilistic inference" whereby an assessment is made of the probability of a conclusion being true based on information which goes beyond what is stated in the premises.

In reviewing the literature on negations and on syllogistic reasoning, we found no study which attempted to bridge the gap between these two areas by systematically investigating subjects' ability to comprehend single premises containing different types of negations. The focus of this study was to investigate people's comprehension ability as a function of the number and type of negations embedded within sentences similar to those which might appear as premises in syllogisms. The stimulus sentences used in this study contained the quantifiers "all" or "some", and one of two different types of categories. One type of category consisted of a single word, while the other type of category consisted of a multi-word phrase. This category manipulation allowed us to investigate the effect of placing different memory loads on the comprehension process. Further, since single word categories constitute a more common and natural means of classification than multi-word categories*, the category manipulation should also provide information concerning the role

of natural discourse in comprehension.

Finally, because of a lack of parallelism which exists between the English and Spanish languages concerning the meaning of certain constructions containing double negations, it appeared that incorporating a group of Hispanics in our study might prove interesting. In Spanish certain doubly negated constructions retain a negative meaning instead of reverting to an affirmative meaning, as would be the case in grammatically correct English. To appreciate this lack of parallelism, let us consider the following statement: "I do not want any money." A translation of this statement into Spanish results in "yo no quiero ningún dinero", which when literally translated back into English becomes "I do not want no money." The lack of parallelism is due to the Spanish negations "no" and "ningún" (meaning "no" and "none", respectively) which, when appearing together in a sentence, result in an overall negative meaning. Another example of a double negative construction which retains an overall negative meaning in Spanish is the statement "yo no quiero nada" which is the grammatical way of saying "I do not want anything", yet literally translates to "I do not want nothing".

To confuse the issue, the two-negative "neither/nor" construction in English has a completely equivalent and parallel construction in Spanish via the pair "no/ni". The translation of "I want neither money nor fame" becomes "yo no quiero dinero ni fama". However, it would be perfectly acceptable in Spanish to add an additional negation to this statement without changing its meaning by writing "yo no quiero ni dinero ni fama"; to do so in English would not only result in the rather awkward and confusing statement "I do not want neither money nor fame", but also create an ambiguity--in slang usage this means the same as the original statement, but in a strictly grammatical sense it means "I want both money and fame".

Thus, including Hispanics in the study would allow us to investigate whether or not Hispanics are more likely to misinterpret doubly negated

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* For example, compare the categories "boring" and "longer than three hours" in the sentences "not all soccer games are boring" and "not all soccer games take longer than three hours".

statements than are Anglos. Past attempts to investigate this lack of parallelism between English and Spanish have not been conclusive (Mestre, 1982, 1984). However, since indications are that language proficiency mediates many aspects of problem solving for Hispanics (Gerace and Mestre, 1982; Mestre, Gerace and Lochhead, 1982; Mestre, 1981), another attempt to look for a double negative performance difference between Hispanics and Anglos might prove to be an interesting endeavor.

Research Design

Description of Tasks

There were 32 sentences containing one, two or three negations used in the study. Each sentence was presented with a set of multiple choices from which the subjects could choose the one answer they felt was most appropriate. The sentences used were composed of the portions below in the order shown:

(Falsification)(negation)[quantifier][group of similar objects][verb]
(negation)[dichotomous category]

The sections placed in parentheses implies that these portions could, or could not be present depending on the particular sentence, while the portions in the square brackets implies that these portions were always present in the sentences. Below is a description of each of the sentence sections.

Falsification: Two types of falsification were used in sentences where a falsification was present. These were: "It's false that" and "It's not true that".

Negation: The two forms of negation used were the word "not", and contractions where the negation was attached to the verb, such as "aren't".

Quantifier: Two quantifiers were used, namely "all" and "some".

Group of Similar Objects, Verb, and Dichotomous Category: These three portions fit together as a unit to form the Context of the sentence. The following four different Contexts were used, where we have used a slash to separate the group of similar objects, verb, and dichotomous category.

1. The water samples / contain / more than three types of bacteria.

2. The cars / get / more than twenty miles per gallon.
3. Clerks working at the Fitzgerald Company / are / male.
4. Windows in the Martin Tower / are / tinted.

Several aspects should be noted. First, the word "dichotomous" in the term "dichotomous category" implies that any single object from the "group of similar objects" must belong to the category or its complement. In other words, any "clerk" working at the ficticious "Fitzgerald Company" must either be male or female, and similarly, any one of "the cars" must either get more than twenty miles per gallon, or twenty or fewer miles per gallon. One further distinction can be made among dichotomous categories. In Contexts 1 and 2 above, the dichotomous categories are Continuous since there is a continuous range of values into which any single object from the "group of similar objects" could be mapped; that is, any one of the "water samples" can contain any number of different types of bacteria, while any one of the "cars" can get anywhere from five miles per gallon (for an untuned gas-guzzler) to fifty miles per gallon (for a tuned economy car being helped by a stong tailwind). In Contexts 3 and 4, the dichotomous categories are Discrete since there are only two possible choices into which any single object from the "group of similar objects" could be mapped; that is, any "clerk" must be either male or female, while any "window" must be either tinted or clear.

With the general form given above and avoiding the awkward construction "not some", there are a total of twelve possible Sentence Types that can be constructed. Out of these twelve Sentences Types, eight were used as stimulus sentences while the remaining four were chosen to comprise the set of multiple choice answers for the eight Sentence Types. The four multiple choice answers spanned all possible alternatives. Two of the four multiple choice answers contained one negative immediately preceding the dichotomous category; since the focus of the study was to investigate subjects' understanding of sentences with negations, a decision was made to have all multiple choice answers phrased in the affirmative. Therefore, whenever a negation preceded the dichotomous category in a multiple choice answer, the category's complement was used (for example, "not male" became "female"). A sample of the eight Sentence Types for Context 3, along with the set of four multiple choice answers presented with each sentence is given below:

Sentences Types for Context 3:

1) Not all of the clerks working at the Fitzgerald Company are male

2) Not all of the clerks working at the Fitzgerald Company are not male

3) It's not true that all of the clerks working at the Fitzgerald Company are male

4) It's not true that all of the clerks working at the Fitzgerald Company are not male

5) It's not true that not all of the clerks working at the Fitzgerald Company are male

6) It's not true that not all of the clerks working at the Fitzgerald Company are not male

7) It's not true that some of the clerks working at the Fitzgerald Company are male

8) It's not true that some of the clerks working at the Fitzgerald Company are not male

Multiple Choice Answer Set:

A) All of the clerks working at the Fitzgerald Company are male

B) Some of the clerks working at the Fitzgerald Company are male

C) All of the clerks working at the Fitzgerald Company are female

D) Some of the clerks working at the Fitzgerald Company are female

Since there are eight Sentence Types and four Contexts, a total of 32 sentences can be constructed which comprise the Stimulus Sentence Set given to the subject. All eight sentences in each of the four Contexts were presented with the set of four multiple choices corresponding to that Context. The answers were balanced over the eight Sentence Types with each of the four answers corresponding to exactly two Sentence Types. The table below shows which answer goes with which Sentence Type.

	Sentence Type							
	1	2	3	4	5	6	7	8
Answer:	D	B	D	B	A	C	C	A

Three other Stimulus Sentence Sets were used. In the second Stimulus Sentence Set, the group of similar objects for each sentence was placed at the beginning, while the falsification, quantifier, negations and dichotomous category was placed at the end. For example, Sentence Type 4 for Context 3 had the following form:

Concerning the clerks working at the Fitzgerald Company, it's not true that all are not male

Similarly, the answer set for Stimulus Sentence Set 2 took the form:

Concerning the clerks working at the Fitzgerald Company,
A) All are male
B) Some are male
C) All are female
D) Some are female

This particular manipulation in the phrasing was made to see if moving those portions of the sentence which did not play a significant role in determining the meaning of the sentence to the beginning of the sentence would improve comprehension.

Stimulus Sentence Set 3 differed from the first set in the form used for falsification and negation. The falsification "it's false that" was always used for all four Contexts, and all negations immediately preceding the dichotomous category were combined with the verb "are" to make "aren't" for Contexts 3 and 4. Sentence Type 4 for Context 3 in Stimulus Sentence Set 3 takes the form:

It's false that all of the clerks working at the Fitzgerald Company aren't male

The answer set for Stimulus Sentence Set 3 was exactly the same as the answer set for Stimulus Sentence Set 1. This manipulation was motivated by research findings obtained by Vazquez (1981) in which the form of falsification used appeared to affect the strategy employed by the subjects.

Stimulus Sentence Set 4 differed from the first set only in the multiple choice answers presented with the sentences -- now there was a fifth answer presented with the set of multiple choice answers. This fifth choice took the form: E) Some of the clerks working at the Fitzgerald Company are male, and some are female. This final manipulation was motivated by comments made by several subjects participating in a pilot study indicating that they would have liked to have a choice which said "some of each".

A summary of all Stimulus Sentence Sets for all four Contexts, multiple choice answers, and groups to which the sentence set was administered, is given in the Appendix.

Subjects

The subjects participating in the study were divided into five groups. All subjects were undergraduates majoring in the sciences and engineering at a major eastern State university. The first group consisted of 11 Hispanic subjects. The remaining four groups each consited of 15 Anglo subjects. All subjects volunteered to participate in the study and were paid for their time. The Hispanic group and one of the Anglo groups was given Stimulus Sentence Set 1; these two groups will be denoted as H and A1, respectively. The remaining three Anglo groups were given one of the three remaining Stimulus Sentence Sets. We will denote these three groups as A2, A3, and A4, and the number following the letter "A" denotes the Stimulus Sentence Set given to that group.

Procedure

The 60 Anglo subjects were assigned randomly to groups A1 through A4. The subjects were run singly or in pairs over a one month period. For each experimental session, an experimenter told the subject(s) that they were about to participate in a research project investigating how students interpreted complex sentences. Subjects were then given written instructions to read. The instructions told the subjects that 32 sentences would be presented, one at a time, with a set of multiple choice answers. Their job was "to pick the one choice that conveys the equivalent information as the original sentence". The instructions also indicated that the sentences would only deal with the following four topics: 1) The number of different types of bacteria that a group of water samples contain, 2) The mileage that a particular group of cars gets, 3) The gender of of the clerks working at a company called the "Fitzgerald Company", and 4) The type of windows in a building called the "Martin Tower". The instructions stated that the same set of multiple choice answers would be given for all of the sentences belonging to the same topic,

and that these multiple choice answers would always appear in the same order. A list of the four sets of multiple choice answers were included in the instructions for the subjects' perusal. The subjects were further warned that although many of the sentences dealing with a particular topic would sound similar, all sentences differed slightly from one another and that they should therefore be very careful reading each sentence.

The sentences were presented via a computer screen using a Wang VS-80 minicomputer. Subjects were told to answer each question by pressing prominently marked keys on the keyboard. After the first 16 sentences, subjects were given an opportunity to take a short break before moving on to the second 16 sentences. We will refer to the first 16 sentences given to a subject as Round 1, and the second 16 sentences as Round 2.

The sentences were presented in a pseudo-random fashion--that is, randomly but subject to the following two constraints:

1. Discrete and Continuous sentences were alternated. That is, if a subject just selected an answer involving a sentence from a Discrete Context (i.e. Contexts 3 or 4), then the next sentence that the subject would see would be one from a Continuous Context (i.e. Contexts 1 or 2). This constraint means that in the 16 sentences of Round 1 (and the 16 sentences of Round 2) the subject saw 8 Discrete sentences and 8 Continuous sentences.

2. The second constraint imposed was that the 8 Discrete, and 8 Continous sentences of a particular Round were each comprised of a complete set of the eight Sentence Types listed in page 7. This does not mean that Round 1 consisted of all 8 Sentence Types for a particular Discrete Context, and 8 Sentence Types for a particular Continuous Context; each Round contained one complete set of 8 Sentence Types with a "Discrete mixture" of Contexts 3 and 4, and one complete set of 8 Sentence Types with a "Continuous mixture" of Contexts 1 and 2.

Between every sentence, a screen appeared which told the subject a) the number of questions s/he had answered and the number of questions left to go, and b) to press the "return" key whenever s/he was ready to receive another sentence. When a subject wanted to receive another sentence and pressed "return", a new sentence with its multiple choice answer set would instantaneously appear on the screen, and a timer would be triggered which recorded the number of seconds it took the subject to select an answer. It is important to note that subjects were not told that the computer was recording the length of time it took them to answer each question. The reason for this

was that we were interested in an assessment of each subject's processing time under "natural circumstances".

The experimenter answered any questions that subjects had concerning the instructions or the computer before the data collection was begun. Experimental sessions took in the range of 30-45 minutes, while the amount of time that subjects actually spent on task was in the range of 15-30 minutes. The data recorded by the computer consisted of:

1. The order in which each sentence was presented (from 1 to 32). The first 16 sentences which comprised Round 1 and the second 16 sentences which comprised Round 2.

2. The Context of the sentence. Note that knowing which of the four Contexts the sentence came from also determines whether the sentence is Discrete or Continuous.

3. The Sentence Type, i.e. a number between 1 and 8.

4. The time measured in seconds that it took the subject to answer each question.

5. The subject's answer.

Results

Means and standard deviations for all five groups on the sentence tasks are reported in Table 1. The performance, given as the entry labeled "percent correct", is subdivided into "Continuous" and "Discrete" corresponding to the 16 sentences from Contexts 1 and 2, and the 16 sentences from Contexts 3 and 4, respectively; the "total" entry consists of averaging over all 32 sentences. The "latency" entries are similarly subdivided. Also shown in Table 1 is each groups' Grade Point Average. It is evident from Table 1 that all groups performed better on the Discrete sentences than in the Continuous sentences. Similarly, the Discrete sentences took less time to answer than the Continuous sentences for all groups. There is a disparity in the latency

between the Hispanic group and the remaining four Anglo groups. There does not appear to be any disparity among groups H, A1, A2, and A3 as measured by performance or by Grade Point Average. The substantially lower means for the A4 group is expected since this group was given Stimulus Sentence Set 4 which contained a fifth multiple choice answer as compared to four multiple choice answers for the other three Stimulus Sentence Sets.

Table 2 contains correlation coefficients among selected variables. The five entries in Table 2 correspond to the groups H, A1, A2, A3, and A4, respectively. The correlations of Grade Point Average with performance are consistently positive and either significant, or approaching significance, except for group A2 which exhibited a null correlation. The correlation of latency with performance or with Grade Point Average is not strong. It appears from the data at hand that performance on the Discrete sentences is a better predictor of Grade Point Average than is performance on the Continuous sentences.

Figure 1 gives a detailed breakdown of each group's performance in the eight Sentence Types for Continuous and Discrete sentences separately. Figures 2 and 3 show the groups' performance and latency as a function of the number of negations in the Continuous and Discrete sentences separately.

Before proceeding further, we would like to deal with an issue concerning group A4. As mentioned earlier, this group received Stimulus Sentence Set 4 which mainly differed from the other three Stimulus Sentence Sets by virtue of its five multiple choice answers. Because of this, it would be inappropriate to carry out comparisons involving group A4 and the other four groups. Thus, we will briefly review the salient features of the performance of group A4, and restrict the remainder of this section to analyses among groups H, A1, A2, and A3. It appears as though the vast majority of subjects in group A4 preferred the "some of each" answer in numerous instances over the other four answer -- thirteen out of the fifteen subjects in this group chose answer "E" at least once. On the average, a subject from this group chose answer "E" 3.9 times out of the 32 possible times. However, this number in somewhat misleading since one subject chose answer "E" 17 times; discounting this subject would drop the average number of times answer "E" was selected per subject to 2.8 . Overall, the total number of "E" answers was equally divided

between Discrete and Continuous sentences; however, there was a higher tendency to choose "E" when the correct answer was one of the two "some..." choices than when the correct answer was one of the two "all..." choices.

Several statistical analyses were carried out. The first concerns Continuous Contexts 1 and 2 and Discrete Contexts 3 and 4. Our analyses revealed that, for all five groups, no significant difference existed in performance between Continuous Contexts 1 and 2; neither were there any significant differences in performance between Discrete Contexts 3 and 4. For the latency variable, Continuous Context 1 took significantly longer than Continuous Context 2, $F(1,52)=6.28$ $p<.05$. This difference is likely due to the fact that subjects are more familiar with a context concerning car mileage than with a context concerning the types of bacteria in water samples, and this familiarity resulted in faster response times in the car mileage sentences. Although statistically significant, we do not attach any additional "significance" to this difference. Consequently, for the remainder of this paper, the term "Continuous" will refer to the sentences of Contexts 1 and 2 combined, and the term "Discrete" will refer to the sentences of Contexts 3 and 4 combined. The rest of the analyses are subdivided by topic.

Performance Analysis: A Group(H, A1, A2, A3) x Context(Continuous vs. Discrete) x Sentence Type analysis of variance was carried out for performance as measured by percent correct. No group main effect was present implying that the performance among the four groups did not differ appreciably. Performance did differ significantly among Sentence Types, $F(7,364)=9.31$ $p<.001$. There was also a Context main effect -- averaged over Sentence Type, performance on Discrete sentences was significantly better than on Continuous sentences, $F(1,52)=12.41$ $p<.001$. However, there was a Sentence Type x Context interaction, $F(7,364)=7.08$ $p<.001$, indicating that the difference in performance between Discrete and Continuous sentences varied significantly as a function of Sentence Type. The same pattern emerged for any other analysis of variance in which pairs of groups were compared.

Latency Analysis: All three main effects were significant in a Group x Context x Sentence Type analysis of variance for the latency dependent variable. The latency varied significantly across groups, $F(1,52)=3.32$ $p<.05$, and across Sentence Type, $F(7,364)=18.79$ $p<.001$, with the

Continuous sentences taking significantly longer than the Discrete sentences, $F(1,52)=56.54$ $p<.001$. In addition, there was a Group by Context interaction, $F(3,52)=3.12$ $p<.05$, indicating that the difference in latency between Discrete and Continuous sentences varied significantly across groups, and this Context x Group interaction also varied across Sentence Type, $F(21,364)=1.73$ $p<.05$. In similar ANOVAS where the groups were restricted to pairs from among H, A1, A2, and A3, the latency for the Hispanic group was significantly longer than the latency for each of the three Anglo groups. However, the three Anglo groups did not show any pair wise differences in latency. Although there existed a consistent pattern of significant main effects for Context and Sentence Type in all group-pair ANOVAS, no consistent patterns emerged for interactions among the Group, Context, and Sentence Type variables.

Rounds Analysis: The effect of Round number on performance and latency was analyzed using a Group x Round x Context x Sentence Type ANOVA. Performance was significantly better in Round 2 than in Round 1, $F(1,66)=6.74$ $p<.05$, indicating that subjects became better with practice. The Round x Context interaction was nearly significant, $F(1,52)=3.87$ $p=.055$, resulting from a tendency for there to be more improvement in performance between Rounds for the Continuous sentences than for the Discrete sentences. For the latency variable, there was a dramatic improvement in speed between Round 1 and Round 2, $F(1,52)=93.42$ $p<.0001$. There were also significant interactions between Round number and Group, $F(3,52)=14.60$ $p<.001$, between Round number and Context, $F(1,52)=14.60$ $p<.001$, and between Round number and Sentence Type, $F(7,364)=2.22$ $p<.005$. These interactions indicate that the improvement in speed in going from Round 1 to Round 2: a) differed across groups, b) was more pronounced for the Continuous sentences than for the Discrete sentences, and c) was not the same across Sentence Types.

Response Preference Analysis: An ANOVA was carried out to investigate whether subjects had a predisposition for choosing either the "some..." answers or the "all..." answers. The ANOVA consisted of a Group(H, A1, A2, A3) x Context x Response Type design, where the "Response Type" variable averaged both "some..." answers together, and both "all..." answers together. The analysis revealed a tendency for subjects to prefer "some..." answers over "all..." answers, $F(1,52)=5.08$ $p<.05$. This tendency was not equivalent over

contexts -- a significant Context by Response Type interaction indicates that more "some..." answers were chosen for the Continuous sentences than for the Discrete sentences. The Group by Response Type interaction approached significance (p=.08).

Negation Analysis: An analysis of the dependence of performance and latency upon the number of negations embedded in the sentences was carried out. The two ANOVAs, one for performance and the other for latency, consisted of a Group x Context x Negation design. The Negation variable grouped together all Sentence Types containing the same number of negations, that is, one-negation Sentence Types 1, 3 and 7 were all grouped together, two-negation Sentence Types 2, 4, 5 and 8 were grouped together, while only one Sentence Type, namely 6, comprised the three-negation group. The performance analysis resulted in a strong Negation main effect, $F(2,104)=12.74$ $p<.0001$, indicating that performance deteriorated as the number of negations increased. In addition, there was a Context by Negation interaction, $F(2,104)=5.85$ $p<.01$, which implies that the decrement in performance as the number of negations increases was more pronounced for Discrete sentences than for Continuous sentences. However, since there was only one Sentence Type comprising the three-negation group, it may be imprudent to attach so much weight to the three-negation sentences. Therefore, another ANOVA on peformance was carried out restricting the Negations variable to only one-, and two-negation sentences. The results of this ANOVA proved extremely interesting. There was no longer a significant Negations main effect indicating that two-negation sentences were not significantly more difficult than one-negation sentences. However, a strong Context by Negations interaction remained, $F(1,52)=12.68$ $p<.001$. This rather surprising result is manifested in Figure 2, where we can see that for group A2, the two-negation Continuous sentences are of the same difficulty as the one-negation continuous sentences, and for groups H and A3, the two-negation Continuous sentences are actually easier than the one-negation Continuous sentences. For the Discrete sentences, Figure 2 shows that there was a monotonic decrement in performance as the number of negations in the sentences increased. The pattern of the latency analysis did not differ depending on whether the three-negation sentences were included in the analysis, or whether they were excluded from the analysis. Only a strong Negation main effect emerged indicating that the latency increased with the number of negations.

The Negations variable did not interact with any other variable in the latency analysis (see Figure 3).

Discussion*

The results of this study clearly demonstrate that, compared to the Continuous sentences, the Discrete sentences a) took substantially less time to process, and b) were substantially easier to comprehend. Why is this so? We attribute these differences in performance and latency between Continuous and Discrete sentences to two factors. The first factor has to do with the limited capabilities of short term memory (STM). Since the work space in STM is at a premium (Hunt, 1978; Miller, 1956), it is not unreasonable to expect that those sentences with less "essential sentence data" will impose lighter memory loads in STM, and will consequently be more "decipherable" because more work space in STM can be devoted to the processing and comprehension processes. For a given Sentence Type, a Discrete sentence contains less "essential sentence data" to take up space in STM than the corresponding Continuous sentence. The example we are about to give will serve to illustrate this point, as well as define what we mean by "essential sentence data". Let us compare a Continuous with a Discrete sentence from Sentence Type 3:

> It's not true that all of the water samples contain more than three types of bacteria
>
> It's not true that all clerks working at the Fitzgerald Company are male.

The essential sentence data needed by STM to process and decipher the Continuous sentence above is "not true, all samples contain more than three types of bacteria"; for the Discrete sentence, the essential sentence data is

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* As was the case in the previous section, it will be understood that any time the term "groups" is used in this section will exclude group A4, since the Stimulus Sentence Set given to this group would make any comparisons between A4 and the other four groups difficult.

considerably less -- "not true, all clerks are male". Thus, Continuous dichotomous categories impose substantially less memory loads than do Discrete dichotomous categories.

A second factor contributing to the significantly better performance exhibited in the Discrete sentences concerns a facilitation effect deriving from the role that natural discourse plays in daily communication and comprehension. To illustrate, let us consider the Discrete sentence "It's not true that all clerks are male". This is not an unusual statement, either in terms of content or structure; it is, in fact, a sentence which we would not be surprised to hear in conversation. Upon hearing this sentence, most of us would automatically interpret it correctly to mean "some clerks are female". On the other hand, the Continuous sentence "It's not true that all of the water samples contain more than three types of bacteria" is a somewhat stilted sentence which we are less likely to hear in conversation, and the correct interpretation, namely "some of the water samples contain three or fewer types of bacteria," is certainly less automatic in this case than in the Discrete case. It also appears that language is more naturally suited for dealing with Discrete categories due to the succinctness of a single word representation and not so naturally suited for the more cumbersome multi-word representation required for Continuous categories. The results of the Rounds analysis shows that with practice, both latency and performance improve for the Continuous sentences, but not for the Discrete sentences; this implies that as subjects become more familiar with the Continuous sentences, the advantage which Discrete sentences hold over Continuous sentences from the two factors described above diminishes.

The performance on Sentence Type 4 was so unique that it deserves special attention. Figure 1 shows that Sentence Type 4 was the only case where the performance on the Continuous sentences was substantially better than the performance in the Discrete sentences. This inordinately poor performance on the Discrete sentences is largely due to an interpretational ambiguity present in natural discourse. This ambiguity becomes readily apparent if we consider the inner kernel of Sentence Type 4 for Discrete Context 3:

All of the clerks are not male

Depending on the words we choose to emphasize, this statement could take on two different meanings. If we read it aloud emphasizing the words "not male", then it means "all of the clerks are female" which is the correct interpretation. If, on the other hand, we read the statement aloud placing a slightly higher inflection on the word "clerks", then by the "rules" of natural discourse the statement means "some of the clerks are female"; this is tantamount to equating the original statement to "not all of the clerks are male". This ambiguity does not seem to exist for Continuous Context sentences. For example, the corresponding kernel for Continuous Context 1 is:

> All of the water samples contain not more than three types of bacteria

No matter where the emphasis is placed or what inflection is used in reading this sentence aloud, there does not appear to be a natural discourse predilection which automatically elicits the interpretation "some of the water samples contain three or fewer types of bacteria". We appear to be predisposed to treat the "not" and the "more than three types of bacteria" together as an inseparable unit, whereas we are not predisposed to treat the "not" and the "male" in the Discrete statement as an inseparable unit. In order to create a similar ambiguity in the Continuous sentence above, we sould have to phrase it as follows: "All water samples don't contain more than three types of bacteria." If we now place a slightly higher inflection on the words "water samples", the statement suggests the meaning "Some water samples contain three or fewer types of bacteria."

The answers subjects chose for Sentence Type 4 are consistent with the explanation offered above. Let us explore which answer a subject is likely to choose if s/he interpreted "all of the clerks are not male" to mean "some of the clerks are female". The subject is next faced with interpreting the statement "It's not true that some of the clerks are female". Being a one-negative Discrete sentence, our data suggest that the subject is likely to interpret this last statement correctly and conclude that "all clerks are male", or choice "A". Thus we would expect to find more subjects will choose answer "A" for the Discrete sentences than for the Continuous sentences in Sentence Type 4. This is borne out by the data -- averaged over groups H, A1,

A2, and A4, answer "A" comprised 45% of all answers in the Discrete-Sentence Type 4 sentences compared to only 21% of all answers for the Continuous-Sentence Type 4 sentences. Such a disparity in the distribution of wrong answers was not found in any other Sentence Type.

There is additional evidence in support of subjects using rules governing comprehension of natural discourse in interpreting the sentences. This evidence comes from analyzing the types of erroneous interpretations made by the subjects. We uncovered five different strategies used by subjects to interpret the sentences. These stragegies were deduced both by analyzing protocols of a different set of subjects who participated in pilot "think aloud" interviews, and by studying the patterns of incorrect responsed selected by the subjects of this study. Table 3 summarizes these five strategies. It is evident from Table 3 that all strategies, except perhaps cancelling negations in pairs, are very reasonable for use in understanding natural discourse.

Perhaps the most interesting finding in this study emerged in the ananysis of performance as a function of the number of negations embedded in the sentences. Similar to previous studies which have investigated the effect of negations upon comprehension, we found that subjects had an extremely difficult time comprehending the sentences containing three negations. The performance in Sentence Type 6 as shown in Figure 1 indicates that the per cent correct hovered around 40% with little difference between the Continuous and the Discrete sentences. However, unlike previous research studies, we found no overall significant decrement in performance between one-negative and two-negative sentences. Further, we are not aware of any study in which performance in a two-negative task was better than in a one-negative task; as Figure 2 illustrates, this study resulted in a better performance in the two-negative Continuous sentences compared to the one-negative Continuous sentences. An explanation will be offered for this finding which hinges on the supposition that subjects process two-negative Continuous sentences differently from the way they process one-negative Discrete, two-negative Discrete, and one-negative Continuous sentences. This explanation will be sufficient to account for the following three findings: a) The better performance on the one-negative Discrete sentences over the one-negative Continuous sentences, b) The better performance in the one-negative Discrete

sentences over the two-negative Discrete sentences, and c) The better performance in the two-negative continuous sentences over the one-negative Continuous sentences.

Let us postulate that subjects rely on the natural discourse facilitation effect in the one-, and two-negative Discrete sentences. That subjects rely on their facility with natural discourse in the one-negative sentences needs little justification; the discussion of Discrete Sentence Type 4 strongly suggests that subjects also rely on natural discourse to interpret two-negative Discrete sentences. We will also postulate that subjects rely on the facilitation effect in the one-negative Continuous sentences; although these sentences do not resemble natural discourse as well as one-negative Discrete sentences, one-negative Continuous sentences resemble natural discourse enough so that subjects will likely rely on their facility comprehending natural discourse to aid them in interpreting these sentences. These two postulates are all that is needed to explain finding a) above. The first postulate coupled with past research findings which indicate that two negations create a larger load on STM than one negation, is enough to explain finding b).

To explain the most unusual finding of these three, namely finding c), we will argue that subjects are not able to rely on the facilitation effect for the two-negative Continuous sentences. The reason being that the load placed on STM due to the complexity of a two-negative Continuous sentence creates cognitive demands which are not aided by facility with comprehending natural discourse. For these sentences, we postulate that the processing mechanism subjects use consists of a procedural parsing approach in which the sentence is processed in portions instead of being processed as a unit, as is likely to be the case when the facilitation effect applies. Paraphrasing a two-negative Continuous sentence with a step-wise parsing approach would help avoid some of the common errors made by relying on natural discourse interpretations.

The only major difference between the Hispanic group and the three Anglo groups was in latency; the Hispanic group was considerably slower in the sentence tasks than were the other three Anglo groups. Since English was the second language for the majority of the Hispanic group, it is not surprising to find a disparity in speed between Hispanics and native English speakers in

tasks involving the reading and processing of complex English sentences. There was no significant difference in performance between the Hispanic group and the other three Anglo groups. This result is interesting in view of recent studies using comparable groups of subjects in which Hispanics have been more prone to errors due to language misinterpretations (Mestre, 1984; Mestre, Gerace and Lochhead, 1982). Thus no direct evidence was uncovered which could be interpreted as interference due to the lack of parallelism between the English and Spanish languages in certain double-negative constructions. This only means that if there is a double-negative interference effect for Hispanics, the sentence tasks of this study are not a good tool for exposing it. Finally, the fact that there were no significant differences in the performance among Anglo groups A1, A2 and A3, implies that the differences in phrasing among Stimulus Sentence Sets 1, 2, and 3 did not play a major role in the subjects' comprehension ability.

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Appendix

Summary of Contexts, Sentence Types and Stimulus Sentence Sets

Contexts

Continuous:

1. The water samples / contain / more than three types of bacteria
2. The cars / get / more than twenty miles per gallon

Discrete:

3. Clerks working at the Fitzgerald Company / are / male
4. Windows in the Martin Tower / are / tinted

Stimulus Sentence Set	Given to Group	
1	H and A1	All Stimulus Sentence
2	A2	Sets contained 32
3	A3	Sentences, 8 for each
4	A4	of the four Contexts

Examples of the Eight Sentence Types for Different Contexts

Stimulus Sentence Set 1 for Continuous Context 1:

1. Not all of the water samples contain more than three types of bacteria.
2. Not all of the water samples contain not more than three types of bacteria.
3. It's not true that all of the water samples contain more than three types of bacteria.
4. It's not true that all of the water samples contain not more than three types of bacteria.
5. It's not true that not all of the water samples contain more than three types of bacteria.
6. It's not true that not all of the water samples contain not more than three types of bacteria.
7. It's not true that some of the water samples contain more than three types of bacteria.
8. It's not true that some of the water samples contain not more than three types of bacteria.

Answer Set:

A. All of the water samples contain more than three types of bacteria.
B. Some of the water samples contain more than three types of bacteria.
C. All of the water samples contain three or fewer types of bacteria.
D. Some of the water samples contain three or fewer types of bacteria.

Stimulus Sentence Set 2 for Continuous Context 2:

1. Concerning the cars, not all get more than twenty miles per gallon.
2. Concerning the cars, not all get not more than twenty miles per gallon.
3. Concerning the cars, it's not true that all get more than twenty miles per gallon.
4. Concerning the cars, it's not true that all get not more more than twenty miles per gallon.
5. Concerning the cars, it's not true that not all get more than twenty miles per gallon.
6. Concerning the cars, it's not true that not all get not more than twenty miles per gallon.
7. Concerning the cars, it's not true that some get more than twenty miles per gallon.
8. Concerning the cars, it's not true that some get not more than twenty miles per gallon.

Answer Set:

Concerning the cars,

A. All get more than twenty miles per gallon.
B. Some get more than twenty miles per gallon.
C. All get twenty or fewer miles per gallon.
D. Some get twenty or fewer miles per gallon.

Stimulus Sentence Set 3 for Continuous Context 3:

1. Not all clerks working at the Fitzgerald Company are male.
2. Not all clerks working at the Fitzgerald Company are not male.
3. It's not true that all clerks working at the Fitzgerald Company are male.
4. It's not true that all clerks working at the Fitzgerald Company are not male.
5. It's not true that not all clerks working at the Fitzgerald Company are male.
6. It's not true that not all clerks working at the Fitzgerald Company are not male.
7. It's not true that some clerks working at the Fitzgerald Company are male.
8. It's not true that some clerks working at the Fitzgerald Company are not male.

Answer Set:

A. All clerks working at the Fitzgerald Company are male.
B. Some clerks working at the Fitzgerald Company are male.
C. All clerks working at the Fitzgerald Company are female.
D. Some clerks working at the Fitzgerald Company are female.
E. Some clerks working at the Fitzgerald company are male.

Stimulus Sentence Set 4 for Continuous Context 4:

1. Not all windows in the Martin Tower are tinted.
2. Not all windows in the Martin Tower are not tinted.
3. It's false that all windows in the Martin Tower are tinted.
4. It's false that all windows in the Martin Tower aren't tinted.
5. It's false that not all windows in the Martin Tower are tinted.
6. It's false that not all wondows in the Martin Tower aren't tinted.
7. It's false that some windows in the Martin Tower are tinted.
8. It's false that some windows in the Martin Tower aren't tinted.

Answer Set:

A. All windows in the Martin Tower are tinted.
B. Some windows in the Martin Tower are tinted.
C. All windows in the Martin Tower are clear.
D. Some windows in the Martin Tower are clear.

Table 1

Means and Standard Deviations (in parentheses)

		Max. Score	Groups H (N=11)	A1 (N=15)	A2 (N=15)	A3 (N=15)	A4 (N=15)
Performance (% correct)	Continuous Sentences	16	8.1 (3.0)	8.8 (3.6)	9.1 (3.3)	9.5 (3.7)	5.7 (4.4)
	Discrete Sentences	16	9.3 (4.1)	10.3 (3.8)	9.8 (2.5)	10.7 (2.7)	7.6 (3.7)
	Total	32	17.4 (6.6)	19.1 (7.3)	18.9 (4.9)	20.2 (6.3)	13.3 (7.7)
Latency per Sentence (sec)	Continuous Sentences	--	59.5 (21.6)	40.8 (13.4)	44.0 (18.3)	39.0 (12.6)	45.0 (16.3)
	Discrete Sentences	--	45.6 (16.9)	34.0 (15.4)	30.7 (14.8)	34.0 (9.5)	35.4 (11.0)
	Total	--	52.6 (18.0)	37.4 (13.9)	37.3 (16.1)	36.5 (10.4)	40.1 (13.4)
Grade Point Average*		4.0	2.94 (.27) (N=10)	3.06 (.43) (N=14)	2.98 (.47) (N=14)	3.12 (.53) (N=15)	3.06 (.43) (N=13)

* Grade Point Average available only for the number of students shown.

Table 2

Pearson Correlation Coefficients
Among Selected Variables

		Latency Per Sentence			Grade Point Average
		Continuous	Discrete	Total	
Performance (% correct)	Continuous	38	---	---	18
		10	---	---	43
		68*	---	---	-11
		14	---	---	53*
		-18	---	---	45
	Discrete	---	16	---	31
		---	19	---	50*
		---	28	---	02
		---	-10	---	44*
		---	-36	---	57*
	Total	---	---	28	28
		---	---	16	48
		---	---	61*	-06
		---	---	07	51*
		---	---	-30	53*
Grade Point Average		-04	-21	-12	---
		45	31	39	---
		-12	-31	-21	---
		42	40	43	---
		16	10	14	---

* Significant beyond the .05 level, two-tail test.
The five entries correspond to groups H, A1, A2, A3, and A4, respectively.
The number of subjects is the same as those shown in Table 1.

Table 3

Incorrect Strategies Used in Sentence Tasks

Strategy	Aplication Example		How Identified
not all = some	not all clerks are male	some clerks are female	via clinical interviews and by observing that almost all incorrect answers in Sentence Type 1 consited of answer "A"
"not true" serves as toggle switch on dichotomous category	not true, all clerks are male	all clerks are female	via clinical interviews and by observing that one of the two wrong answers chosen in Sentence Type 3 was "C"
"not true" serves as toggle switch on quantifiers such that "all" becomes "some" and vice versa	not true, all clerks are male	some clerks are male	via clinical interviews and by observing that the other wrong answer chosen in Sentence Type 3 3 was "B"
cancel negations in pairs	not all clerks are not male	all clerks are male	clinical interviews
interpretational ambiguity in natural language	all clerks are not male (only for Discrete sentence of the form given above)	some clerks are female	clinical interviews and observing difference between Discrete & Continuous answer "A" in Sentence Type 4

Figure 1. Performance of Groups in Each Sentence Type as a Function of Context (Continuous vs. Discrete)

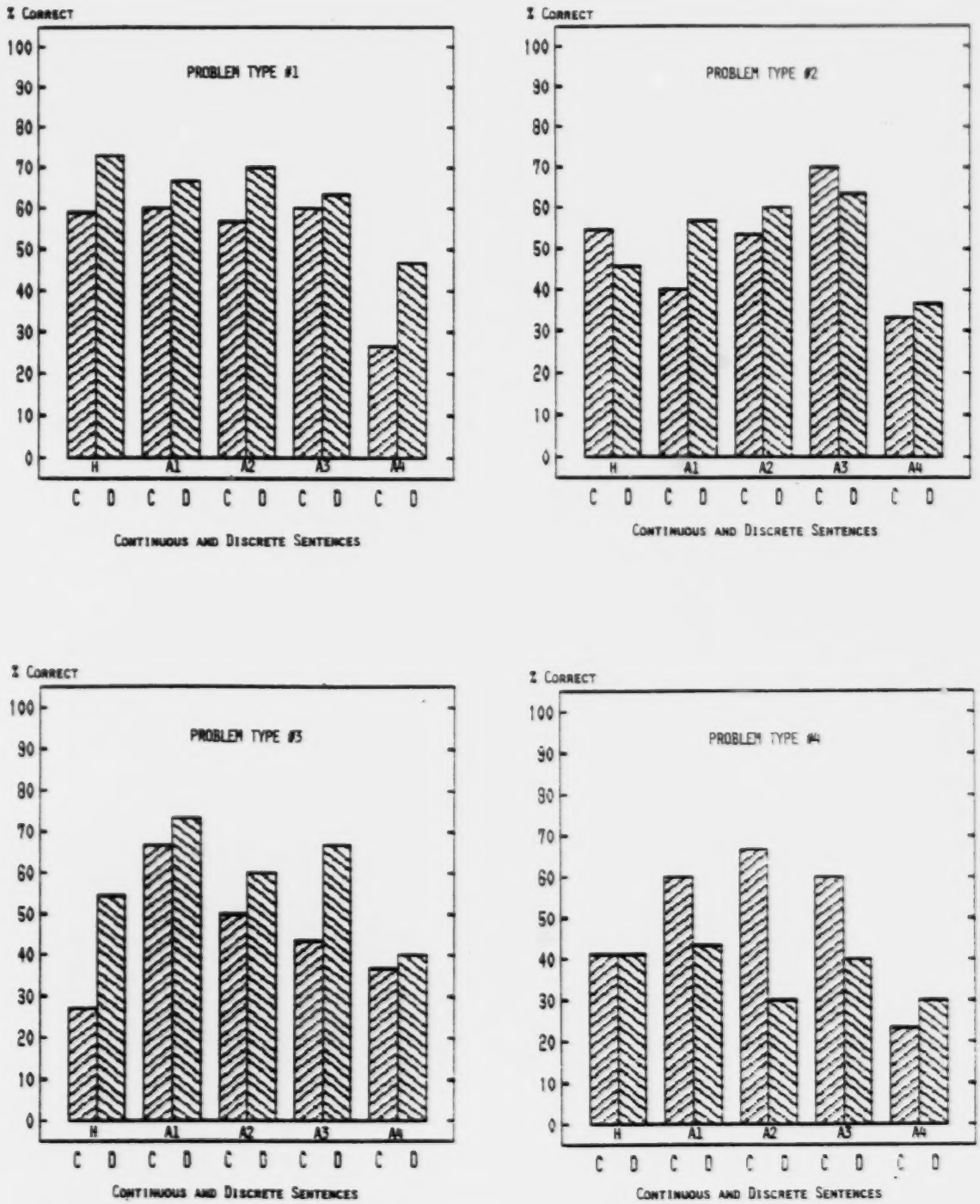
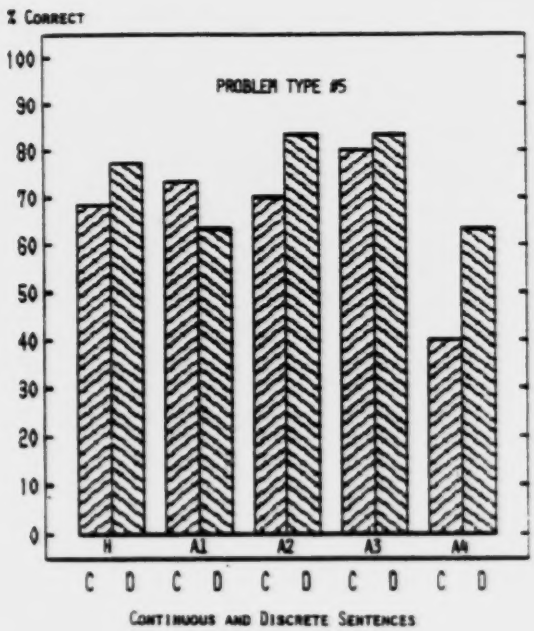
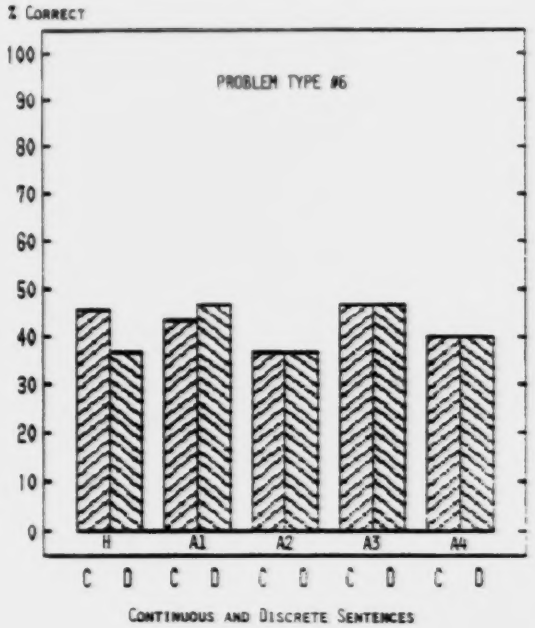
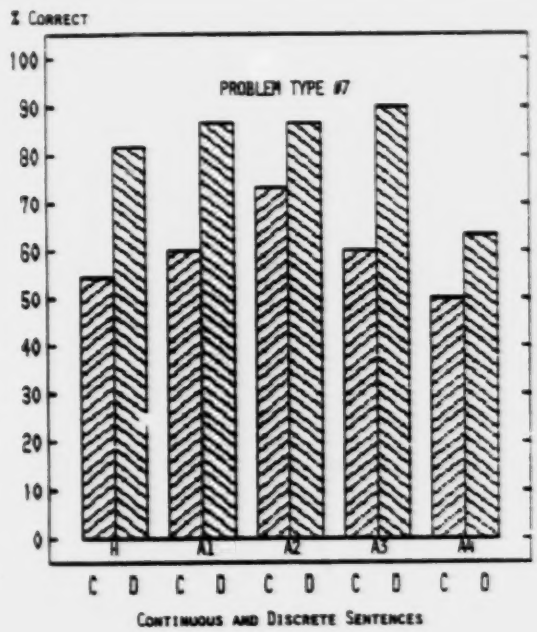
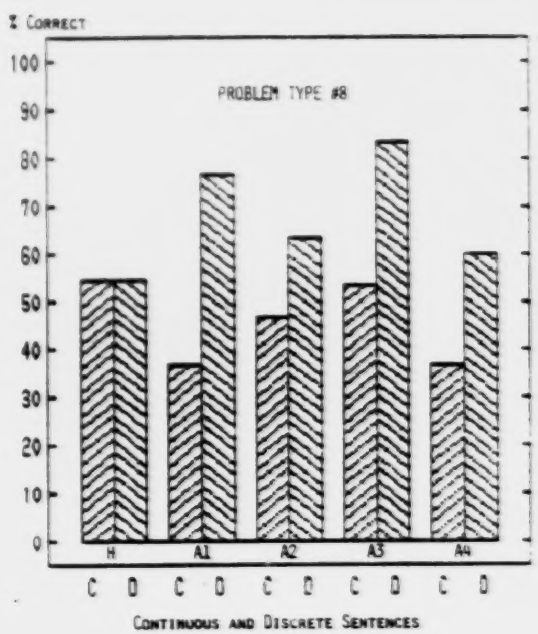


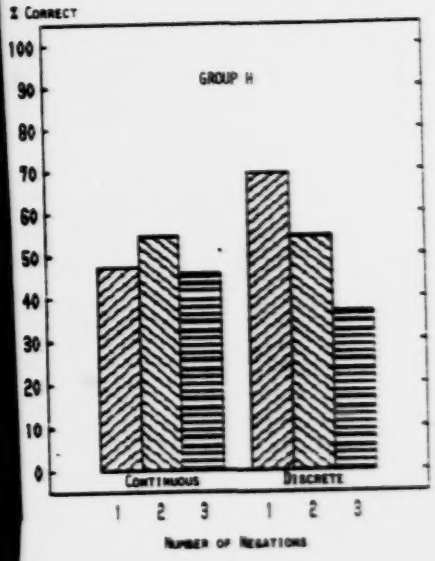
Figure 1. (continued)











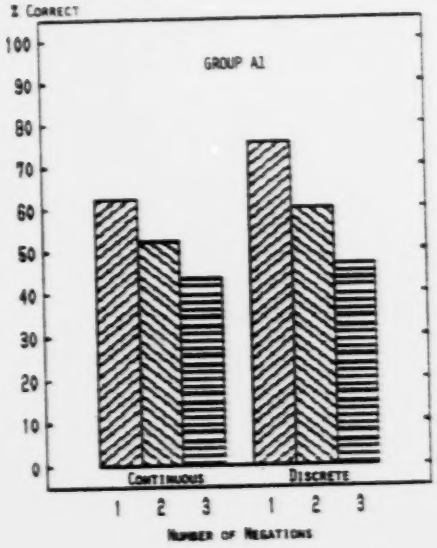
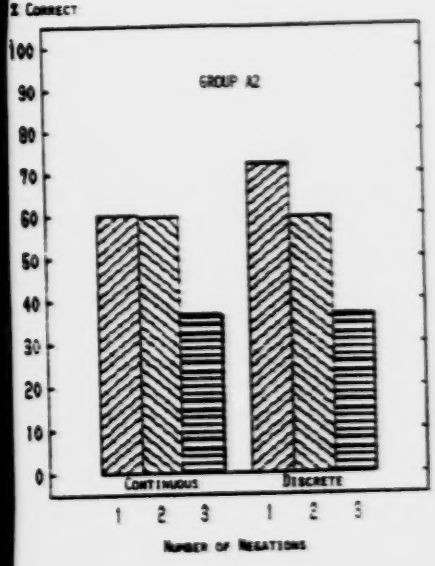
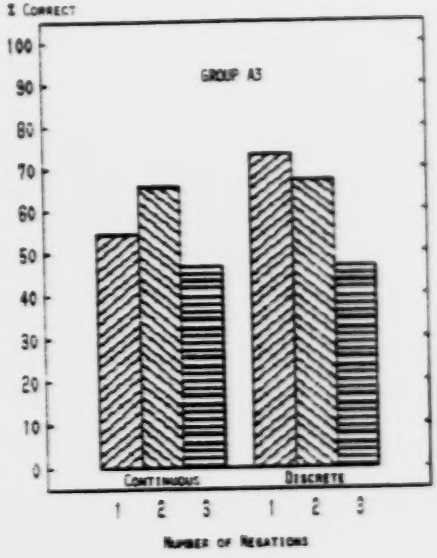
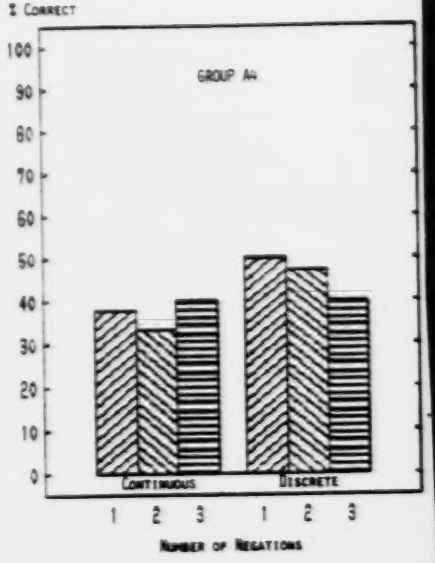


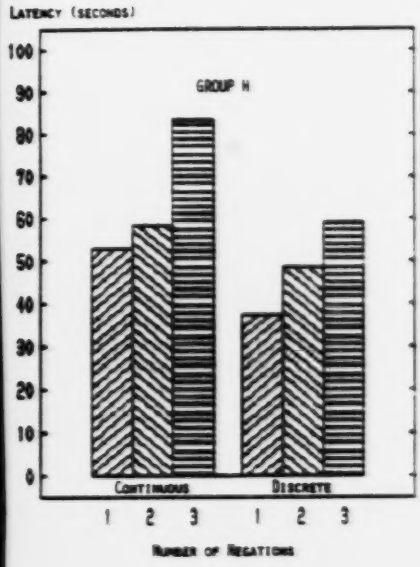
Figure 2.

Performance
in Continuous and Discrete
Sentences for Each Group
as a Function of
Number of Negations









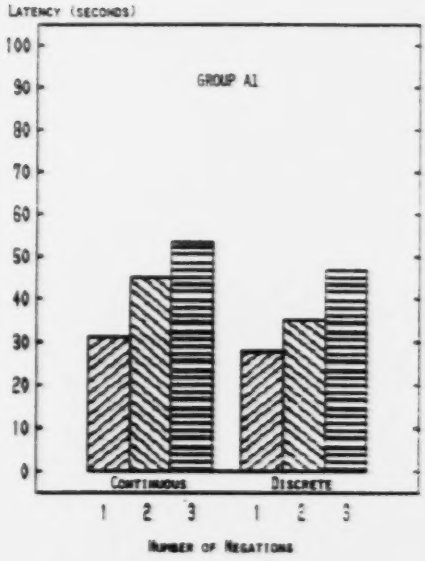


Figure 3.

Latency per Sentence in Continuous and Discrete Sentences for Each Group as a Function of Number of Negations